ATOC 5050: Atmospheric dynamics

Project 1: Boundary layer data analysis project

Due: 5pm, Thursday 19 November 2009 (in class, or deliver to David's office)

Use data collected during our field excursion to answer the following. Some data manipulation and graphing will be needed. This can be done in excel, IDL, Matlab, or by hand. Points will be awarded on the clarity of your analysis methods and explanation of results.

The surface layer: estimate the momentum and heat flux at the surface

Using the field data construct 10 minute averages to give you about 4 different samples to work with. *Repeat the calculations for each 10 minute average to allow you to estimate the mean and standard deviation. The 1 standard deviation error should be quoted with your answer as a measure of observational error. (i.e., quote your answers as* $V_{mean} \pm 1\sigma$*)*

1. Plot wind speed and temperature versus height (4 lines for each of V and T)
2. Assume a logarithmic wind profile in a near neutral surface layer and calculate the wind speed at the reference height of 10 meters.
3. From the data estimate the roughness height and friction velocity, and thus the drag coefficient appropriate for the reference height (10 meters).
4. Compare your result to published values (cite you sources). Comment on agreement or otherwise.
5. Estimate the eddy viscosity and mixing length at 10 and 100 meters. By how many orders of magnitude do these differ from the molecular viscosity and mean free path of air?
6. Compute the (gradient) Richardson over the height of the tower. Is the surface layer best considered stable, neutral or unstable during the experiment?
7. Calculate the momentum flux in the region of the measurements (*i*.e., the drag in units of m/s^2).
8. From Monin-Obukov similarity theory one may write

$$\left(\frac{1}{u_*}\frac{\partial u}{\partial z}\right)^n = \frac{1}{\theta_*}\frac{\partial \theta}{\partial z}$$

   Where n=1 for stable conditions and n=2 for unstable conditions. Use this to estimate the temperature scale θ_* and thus estimate of the sensible heat flux (in units W/m^2) in a manner analogous to the momentum flux. (Hint: $d\theta/dz$ is related to dT/dz by the dry adiabatic lapse rate)

   (*Reminder: give 1 sigma error on all your results*)

Boundary layer wind profiles

1. Calculate the vertical velocity of each balloon. You may assume it is constant.
2. Visit http://www.pilotballoon.com/calculat.htm (or derive your own equations) to estimate *u* and *v* wind components as a function of altitude. Plot the wind speed versus height for each balloon.
3. Download the morning sounding data from Denver for comparison from http://raob.fsl.noaa.gov/ or http://weather.uwyo.edu/upperair/sounding.html and add this to your figure. Do they agree (why, why not)? (*Hint: this may also give you some clues on your calculations!*)
4. Identify the top of the surface layer, the top of the boundary layer, and any other features of note.
5. Construct a hodograph (*v* versus *u*) for the mean of all your balloon data, and superimpose a vector showing the flow from the Denver sounding at 500 hPa.
6. Do you see results that are consistent with an Ekman Spiral? (Explain why/why not)

Note: Holton is a reasonable first place to look for additional insight, but there are better sources. Searching for more information in journal articles on the subject (dating mostly in the 1970s and 80s) and text on boundary layer meteorology and micrometeorology may be helpful. The AMS glossary is a good start.

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Field measurements

Data for windspeed and temperature at 4 heights and wind direction will be logged.
We need about 40 minutes of data.

Tower heights 1 ________ 2 ________ 3 ________ 4 ________ meters

Other data from hand held sensor:

Surface pressure ______________________ hPa

Surface dewpoint temperature ______________________ C

Surface temperature ______________________ C

Balloon weight 1 ________ 2 ________ 3 ________ grams

Balloon diameter 1 ________ 2 ________ 3 ________ meters

Balloon lift 1 ________ 2 ________ 3 ________ grams

Keep a record or azimuth and elevation angles from the theodolite every 30 seconds for 10 minutes.

Notes: